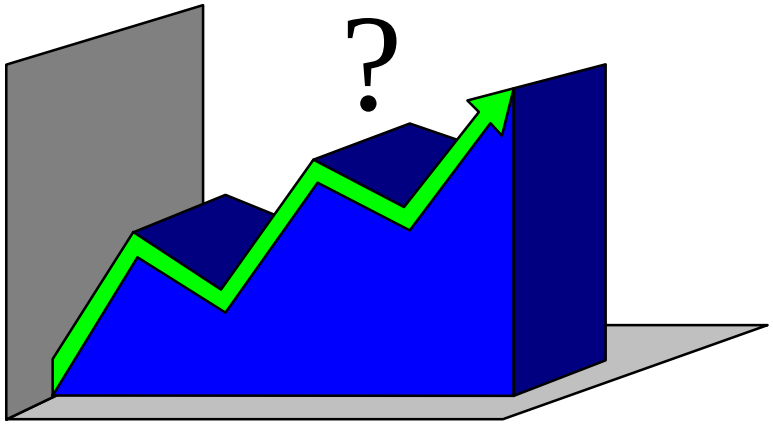
Improved Methods for Estimating Development Costs



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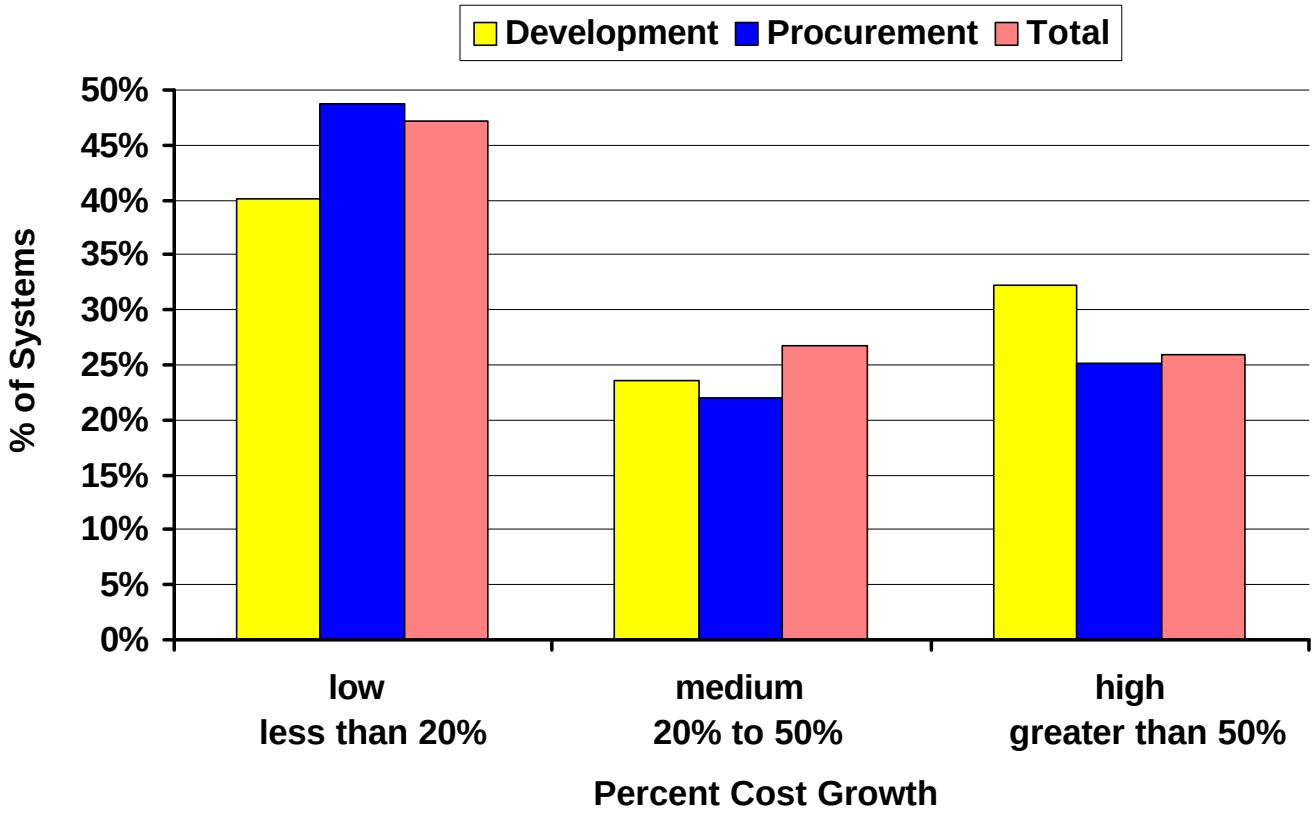
LMI

Agenda

- Background
- An Economic View
- Cost Estimating Methods
- Conduct of Research
- Research Findings and Conclusions

Programs Experiencing Cost Growth



Purpose

- Understand product development processes
- Identify good methods of estimating process costs
- Recommend “best” method

Sources

- Literature/media search
- SME Interviews:
  - ⇒ GPS JPO
  - ⇒ Trimble Navigation, Ltd.
  - ⇒ Marconi North America
  - ⇒ Rockwell-Collins
  - ⇒ Raytheon
  - ⇒ Wright Research Site
- Workshop

Background

Goal: Provide an analytic framework to consider how the existence of a commercial market may affect the development of military electronic items.

Given a commercial market,

i. how do firms react with their bid submission on a military development contract?

ii. how do firms react in competition with each other in the commercial market?

The Problem

- "artificial" downward pressure on cost estimates:

  funding stream inertia

-- vs --

- "real" downward pressure on costs:

  commercial market applicability

A Two-Stage Game

- *Stage 1: Liar's Dice* -- firms submit research and development bids on the military project
  - all else being equal, low bid wins the contract
  - cost-plus contracts mean overruns will be partially compensated
  - firm's problem: optimize its amount of "buy-in" -- or underbidding -- in order to win the contract
  - optimal strategy to eliminate buy-in -- no cost-plus contracts; untenable because of changing criteria

A Two-Stage Game

- *Stage 2: Stackelberg Competition* -- Firms compete as profit maximizers in the commercial market

  - model of imperfect competition: “leader” firm with (n-1) “followers”

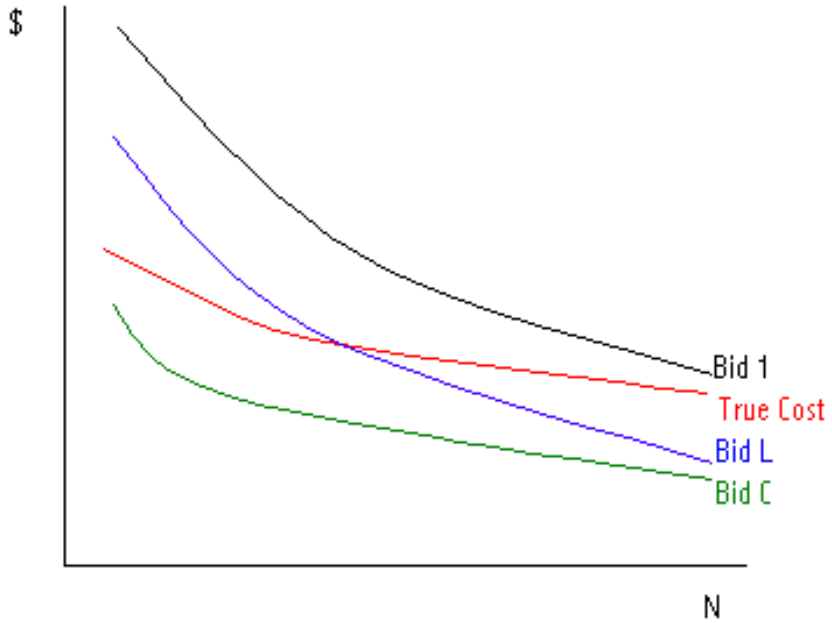
  - “first-mover” advantage -- the leader recognizes how followers will make production decisions and optimizes its behavior accordingly

Winning the military contract confers leadership in the commercial market.

Analytical Framework

Integrating Stackelberg and Liar's Dice

Hypothetical expected winning bid functions



Analytical Framework

Results

- Firms have incentives to underbid actual development costs:
  - percentage of cost overruns reimbursed
  - commercial market advantages of winning the military contract

- The number of firms has an effect on profits and, indirectly, on bidding

Analytical Framework

Conclusions

- For products with a commercial market, military product development costs may be lower

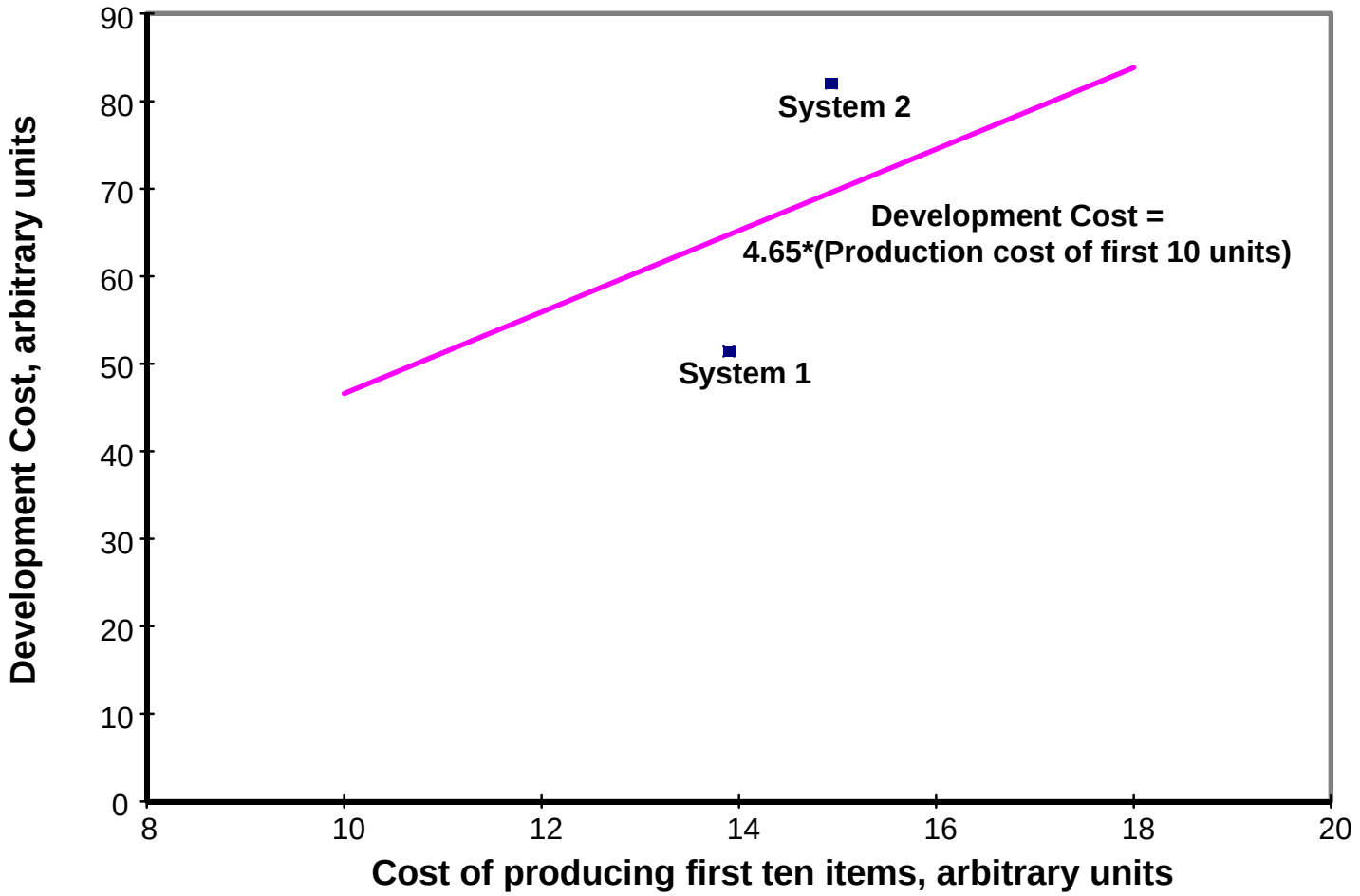
- The amount by which costs are lower will depend on several factors: size of the commercial market, number of firms, ease of technology transfer, etc.

- Commercial market earnings may affect estimates of military product development

Cost Estimating Methods

- Multiple of Production Costs
- Should-Cost Methods
- Decomposition and Analogy
- Parametrics Based on Performance
- Parametrics Based on Performance Trends
- Generalized PERT

Multiple of Initial Production Cost



Multiple of Initial Production Cost

- Development cost = k C_{10}
  - NRE= k_1C_{10}; $T_{1EMD} = k_2C_{10}$; ... ;
- An estimate based on an estimate
- Inflexible

Should-Cost

- Decompose development articles
- Develop standard hours, materials cost, and realization rates for each component, from like-kind data
- Estimate relations between development article costs and non-recurring engineering, program management, test, etc., from like-kind data

Should-Cost

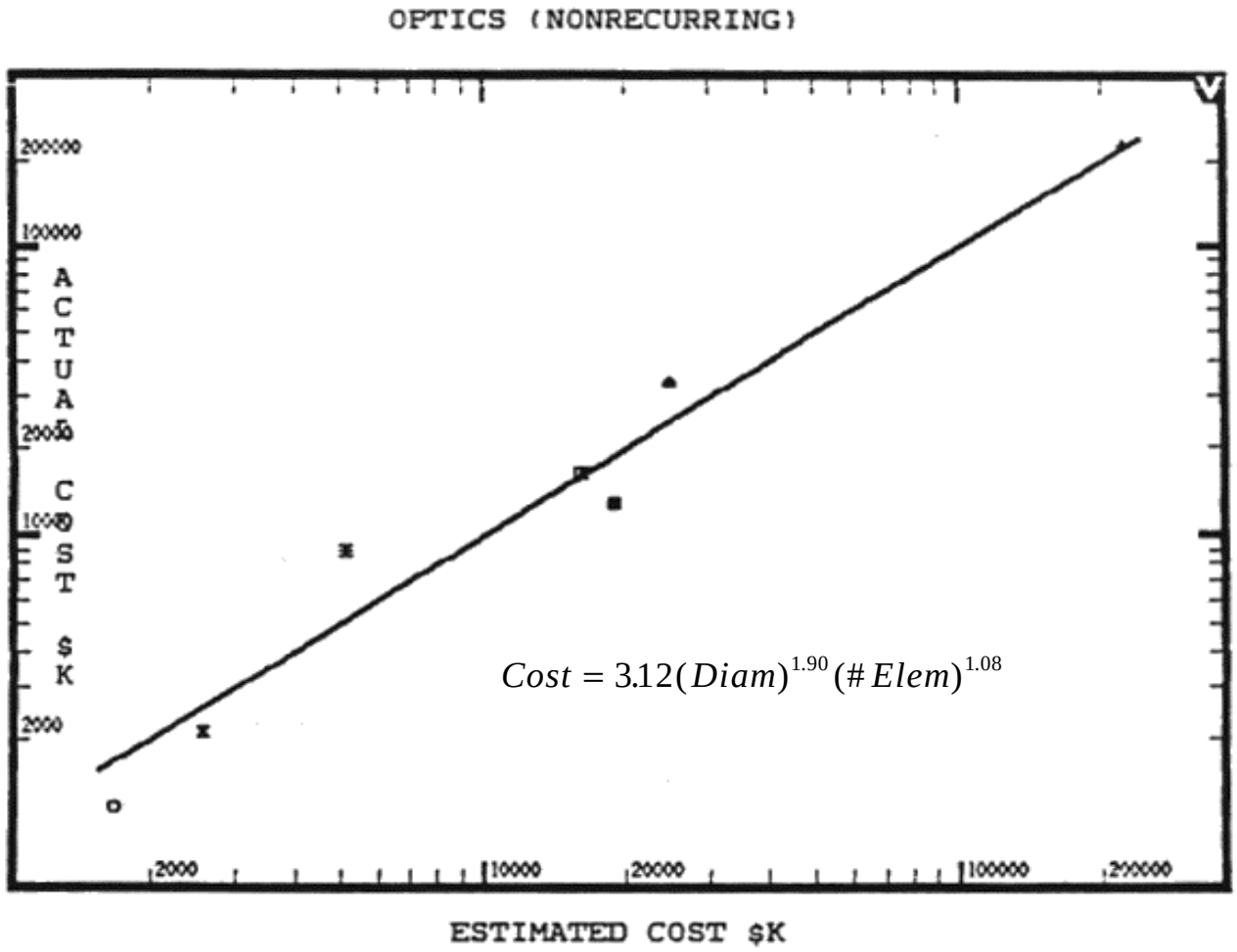
- Somewhat inflexible...
  - but, offer wider opportunities to find data
- Finer decomposition = more flexible…
  - but, finer decomposition means even more data required

Decomposition/analogy

- Decompose development project:
  - Design processes
  - Development manufacturing
  - Test
- Estimate costs of each component by analogies

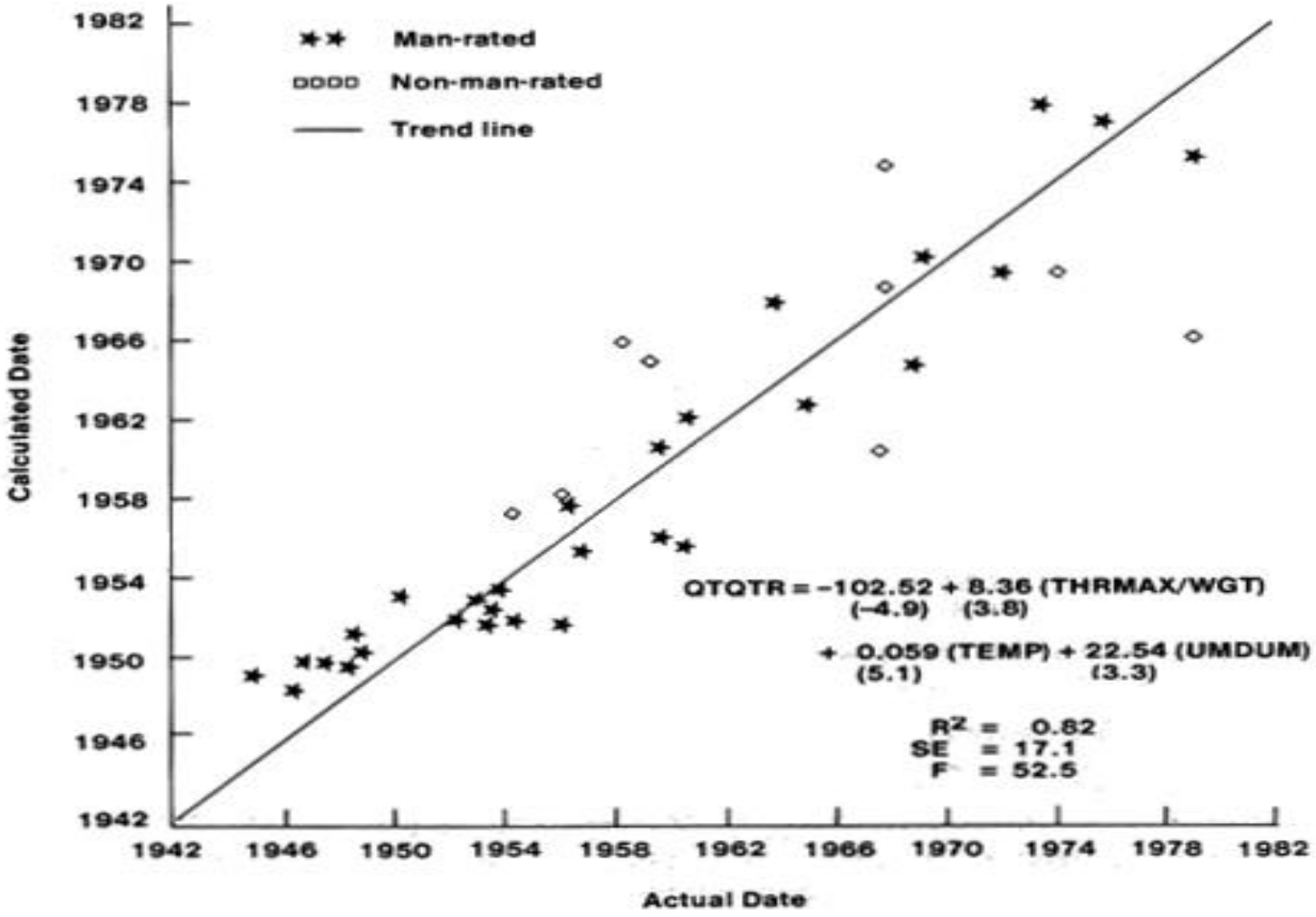
Most widely used method

Function of performance parameters

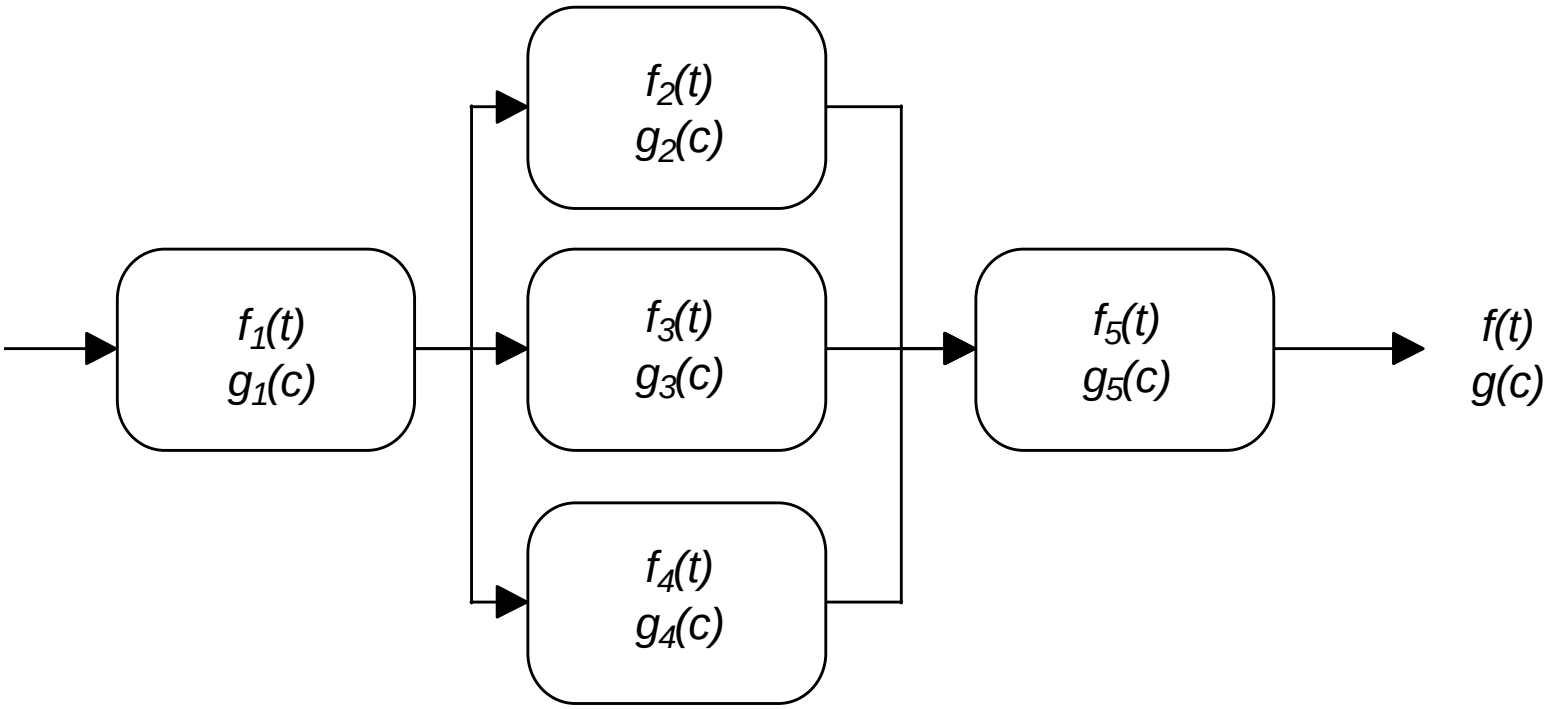


$$Cost = 3.12(Diam)^{1.90}(\#Elem)^{1.08}$$

Function of performance parameters, arrival time, and trends



Generalized PERT



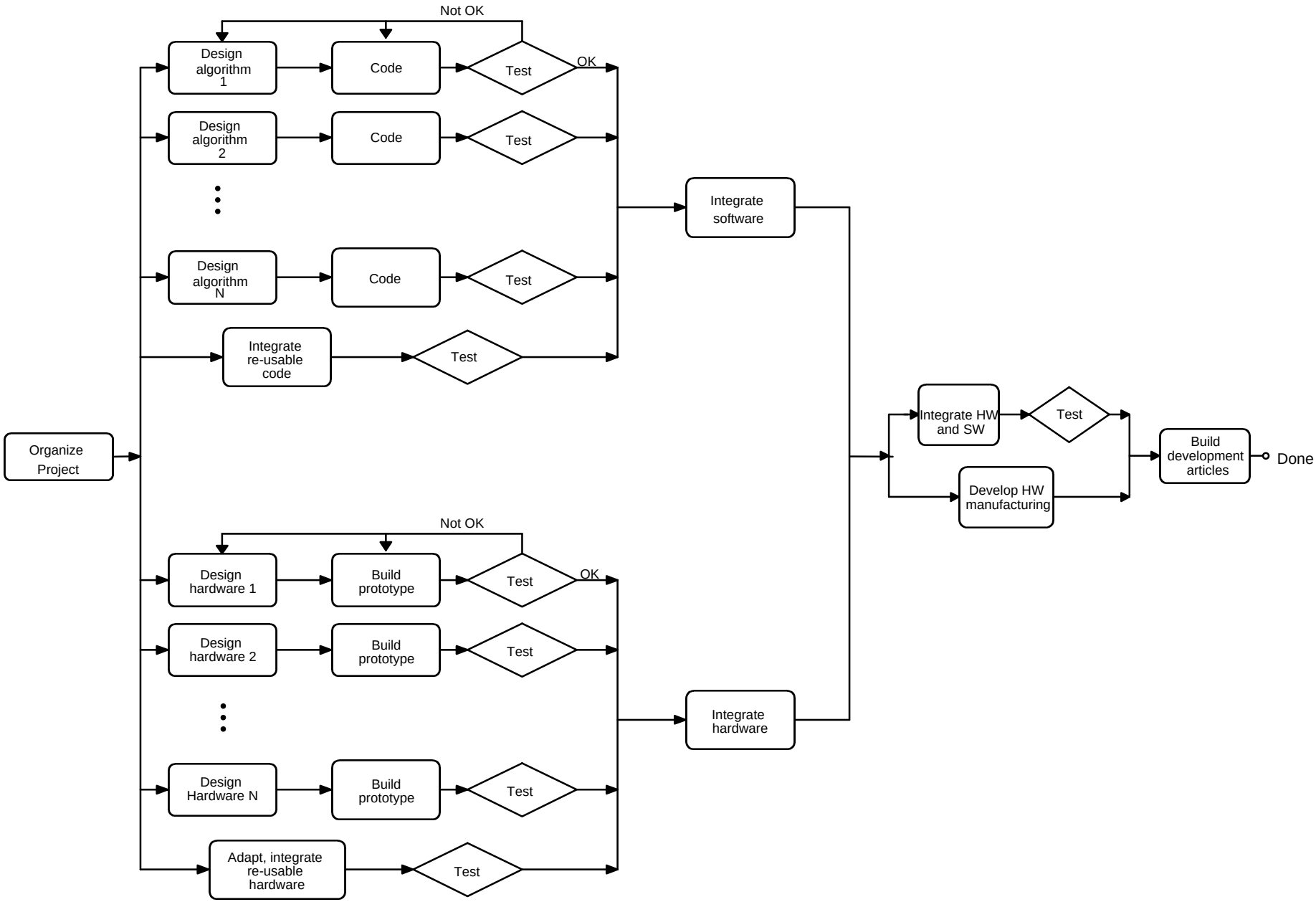
Time, cost distributions

$$f(t) = f_1 * \left[\frac{d}{dt} \left(F_2 F_3 F_4 \right) \right] * f_5$$

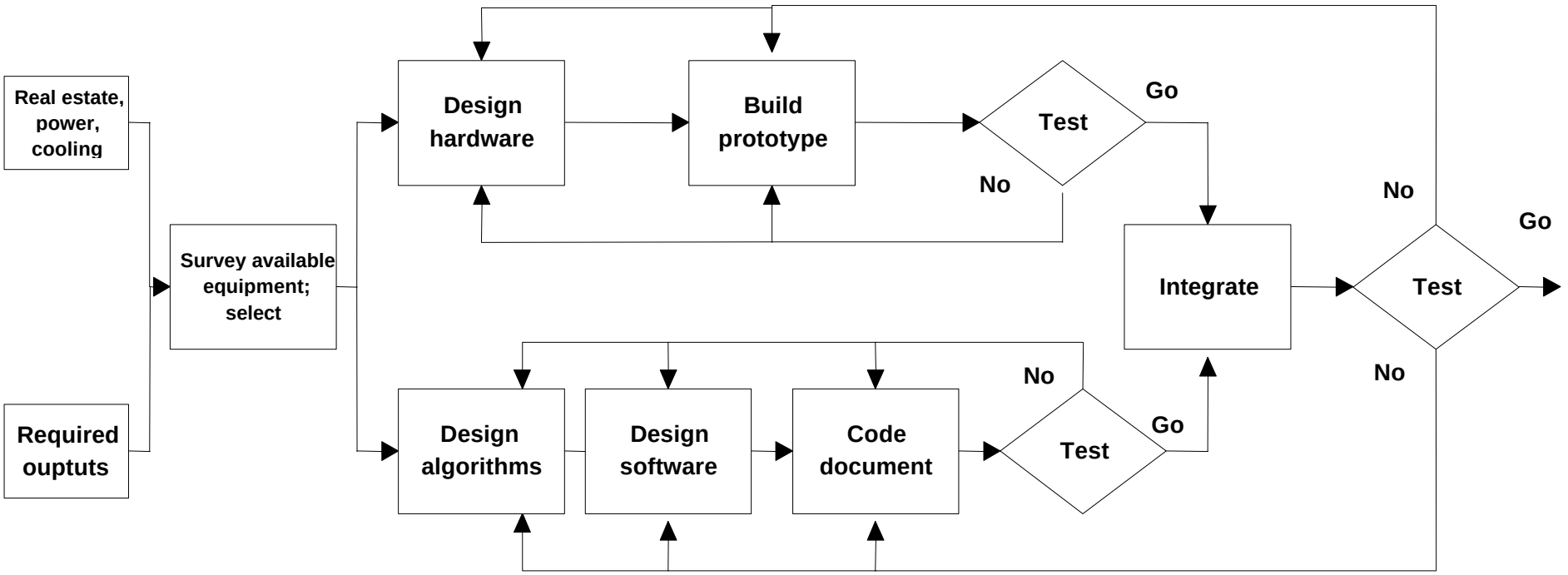
$$F(t) \equiv \int_0^t f(t)\, dt$$

$$g(c) = g_1 * g_2 * g_3 * g_4 * g_5$$

*** denotes convolution**



First-Cut Roadmap of Development Process



Revised Process Development Roadmap

Development Cost Drivers

- Complexity of algorithm development
- Complexity of hardware integration
- Number and variety of interfaces
- Firm’s experience and sophistication

Causes of Cost Overrun

- Schedule slips:
  - ⇒ Optimistic schedule estimates
  - ⇒ Underestimates of integration, test, and rework
  - ⇒ Inadequate specifications and information
- Poor match of people to work
- Software fixes late in the program
- Software size growth
- Technology advances during development
- Unstable funding and/or requirements
- Firm’s inability to manage these factors

Data Requirements

Driver	Data required
Schedule (risk)	• Probabilistic schedule • Amount of integration required
Rework	• Number of functions required • Number of interfaces involved • Rework probabilities
Variety of platforms	• Number of platforms/configs
Technology challenges	• Current tech improvement trends
Institutional experience	• Firm’s history w/ state of the art
Funding stability	• Funding/schedule relations
Requirements stability	• Requirment/schedule relations

Findings

The market landscape has changed:

- Small number of sellers for military unique items
- Decline in influence of the military buyer
- Firms are “eating” NRE
  - ⇒ Retain property rights
  - ⇒ Use patents as trading chits

Findings

New defense acquisition initiatives have resulted in changed product development:

- Military and commercial standards converging
- Roles and responsibilities changing
- Firms perceive higher risk
- New policies encourage developer buy-in
- CAIV complicates cost estimating

Findings

Features of electronics products have changed significantly:

- Higher technology (more gates per chip; ready access to ASICS) call for changes in development activity
- Products must conform to new standards
- Software development now dominates development

Findings

Development processes have changed:

- Firms build around “core” technologies
- Integration and testing activities are now drivers
- Processes are iterative

Findings

Cost estimation:

- Estimation methods unchanged
- Firms do estimates; government validates
- Fewer cost specialists
- Primary method is decomposition and analogy
- Most widely accepted models not used

Bottom line: No acceptable model available